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ABSTRACT

Test items relating to Project Physics Unit 6 are presented in this booklet. Included are 70 multiple-choice and 24 problem-and-essay questions. Nuclear physics fundamentals are examined with respect to the shell model, isotopes, neutrons, protons, nuclides, charge-to-mass ratios, alpha particles, Becquerel's discovery, gamma rays, cyclotrons, nuclear fusion processes, radioactive atoms, decay processes, nuclear binding energies, beta-particle emissions, reactor moderators, half-lives, accelerators, isotopic tracers, transuranium elements, radioactive fallout, and plasmas. Suggestions are made for time consumption in answering some items. Directions and illustrations for explanation purposes are provided. The work of Harvard Project Physics has been financially supported by: the Carnegie Corporation of New York, the Ford Foundation, the National Science Foundation, the Alfred P. Sloan Foundation, the United States Office of Education, and Harvard University. (CC)

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Project Physics **Tests** **6**

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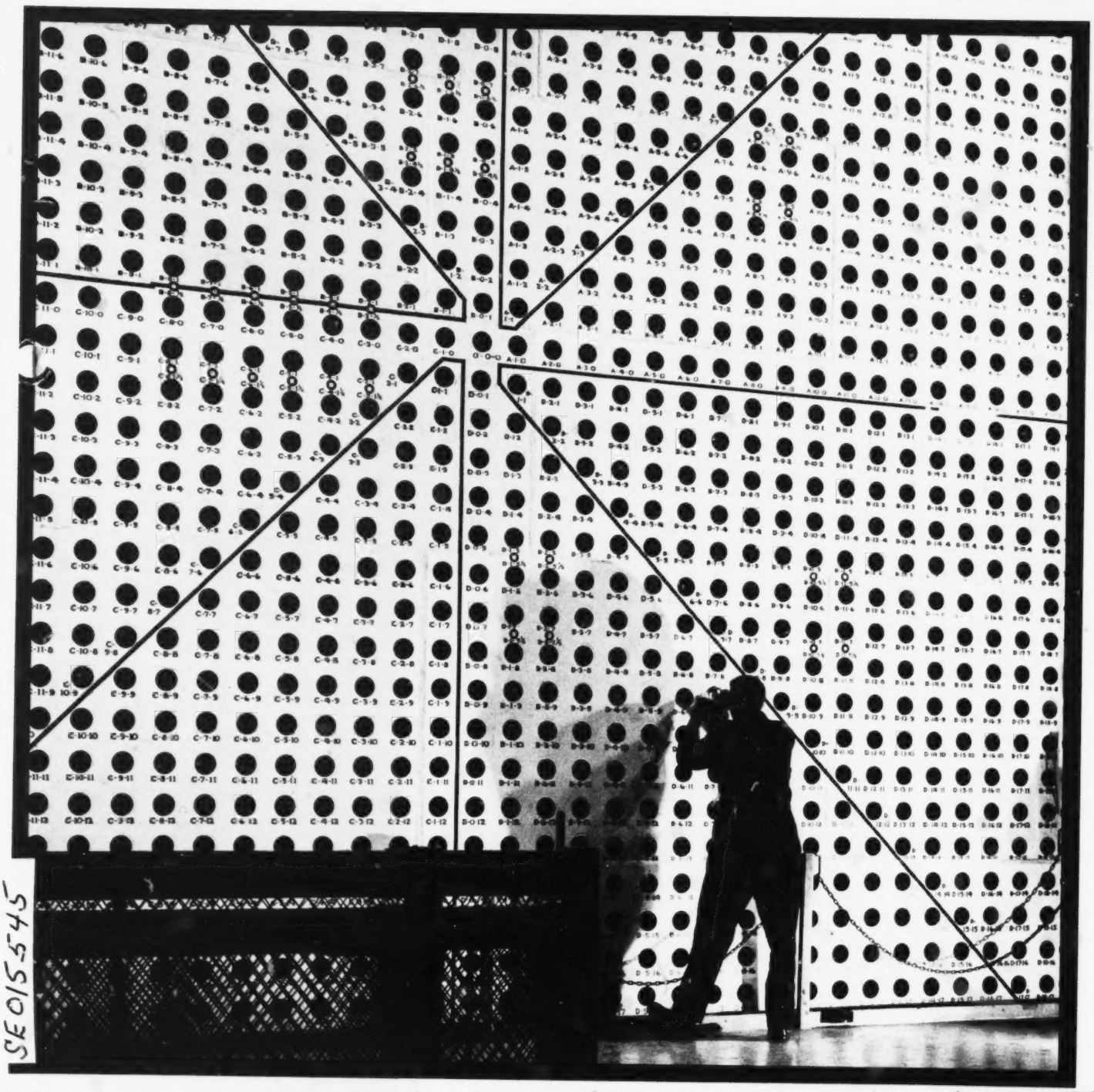
An Introduction to Physics

The Nucleus



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P. 7 Yale University

P. 14 AccuRay

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Test A

Directions

This test consists of fifteen multiple-choice questions and eight problem-and-essay questions, divided into two groups. Answer ALL multiple-choice questions by marking the letter corresponding to the one best answer. Answer THREE of the problem-and-essay questions from Group One and ONE from Group Two. Spend about 15 minutes on the multiple-choice questions, 5 minutes on each of the problem-and-essay questions from Group One and 10 minutes on the problem-and-essay question from Group Two.

Questions 1, 2, and 3 refer to the following statement: An isotope of neon is represented by the symbol $_{10}Ne^{21}$.

1. How many electrons are there in a neutral atom of this isotope?

A. 0
B. 10
C. 11
D. 21
E. 31

2. How many neutrons are in an atom of this isotope?

A. 0
B. 10
C. 11
D. 21
E. 31

3. How many protons are in an atom of this isotope?

A. 0
B. 10
C. 11
D. 21
E. 31

4. The charge-to-mass ratio of an alpha particle is the same as the charge-to-mass ratio of a

A. beta particle.
B. neutron.
C. proton.
D. $_1H^2$ nucleus.
E. $_3Li^7$ nucleus.

5. While looking for the emission of x rays from fluorescent materials, Henri Becquerel discovered a new type of radiation. Which one of the following facts led Becquerel to suspect that the newly discovered rays were different from x rays?

A. The rays could penetrate thick black paper.
B. The rays were capable of producing ionizations in the air.
C. The rays were invisible to the naked eye.
D. The rays could not be started and stopped by the investigator.
E. The rays affected photographic plates.

6. Gamma rays are

A. high frequency electromagnetic radiation.
B. identical to electrons.
C. like electrons, but with a positive charge.
D. nuclei of the element helium.
E. neutral particles with mass number 1.

7. The major function of a cyclotron is

A. to separate isotopes from one another.
B. to detect neutrons.
C. to produce neutrons.
D. to accelerate charged particles.
E. to maintain a chain reaction.

8. Which one of the following processes is an example of nuclear fusion?

A. the formation of water from hydrogen and oxygen
B. the formation of helium from hydrogen
C. the formation of barium and krypton from uranium
D. the formation of lead from radium by radioactive decay
E. the formation of potassium from potash

9. Over a period of time a radioactive atom emits the following particles in succession: alpha, alpha, beta, alpha, beta.

The atomic mass of the end product of this radioactive decay is less than the atomic mass of the original atom by approximately

A. 1 amu.
B. 3 amu.
C. 6 amu.
D. 10 amu.
E. 12 amu.

10. Imagine that a new isotope of lithium with atomic number 3 and mass number 5 has been discovered among the radiations emitted by radioactive plutonium. Which one of the following nuclear equations describes its emission from a $_{94}Pu^{239}$ nucleus?

A. $_{94}Pu^{239} \longrightarrow {}_{3}Li^{5} + {}_{91}Pa^{234}$
B. $_{94}Pu^{239} \longrightarrow {}_{3}Li^{5} + {}_{97}Bk^{244}$
C. $_{94}Pu^{239} \longrightarrow {}_{3}Li^{5} + {}_{91}Pa^{244}$
D. $_{94}Pu^{239} \longrightarrow {}_{5}Li^{3} + {}_{89}Ac^{236}$
E. $_{94}Pu^{239} \longrightarrow {}_{5}Li^{3} + {}_{91}Pa^{234}$

11. A standard way of representing a given nuclide of element X is ${}_{Z}X^{A}$. Which of the following symbols can identify the nuclide completely?

A. A only
B. X only
C. X and Z only
D. A and Z only
E. A, X and Z

12. The chemical properties of an atom are determined by its

A. mass number.
B. number of isotopes.
C. atomic number.
D. nuclear binding energy.

13. A proton of mass m_p and a neutron of mass m_n combine in a fusion process to form a stable deuterium nucleus. The mass of this nucleus is

A. greater than m_p plus m_n.
B. equal to m_p plus m_n.
C. less than m_p plus m_n.
D. sometimes less than and sometimes equal to m_p plus m_n.
E. sometimes greater than and sometimes equal to m_n.

14. According to the proton-neutron theory of the atomic nucleus, beta-particle emission results from

A. a proton changing into an alpha particle.
B. a neutron changing into a proton.
C. a proton expelling an electron from the electron shells of the atom.
D. a gamma ray producing an electron and positron.
E. the loss of one of the electrons in the nucleus.

15. The purpose of a moderator in an atomic reactor is to

A. provide neutrons for the fission process.
B. react with the uranium to release energy.
C. slow down fast neutrons to increase the probability of fission.
D. absorb the dangerous gamma radiation.

TEST A

PROBLEM-AND-ESSAY QUESTIONS

Group One

Answer THREE of the following five questions.

1. The atomic masses of H^1, Li^7 and He^4 are 1.0080 amu, 7.0160 amu, and 4.0026 amu respectively (1 amu = 931 MeV). Calculate in MeV the amount of energy liberated in the following nuclear reaction.

$$_1H^1 + {}_3Li^7 \longrightarrow {}_2He^4 + {}_2He^4$$

2. The following diagram contains the first four members of the uranium-radium series. Supply the missing data.

$$_{92}M^{238} \xrightarrow{\alpha} {}_{?}Th^{?} \xrightarrow{\beta} {}_{?}Pa^{?} \xrightarrow{?} {}_{92}M^{234}$$

3. What is meant by the statement "the law of disintegration of a radioactive substance is a statistical law."

4. A physicist prepares 8 milligrams of pure Po^{218}. If the half-life of Po^{218} is 3.05 minutes, after what time is there only 1 milligram of Po^{218} left?

5. Comment briefly on one of the social consequences of man's ability to control and use atomic energy.

PROBLEM-AND-ESSAY QUESTIONS

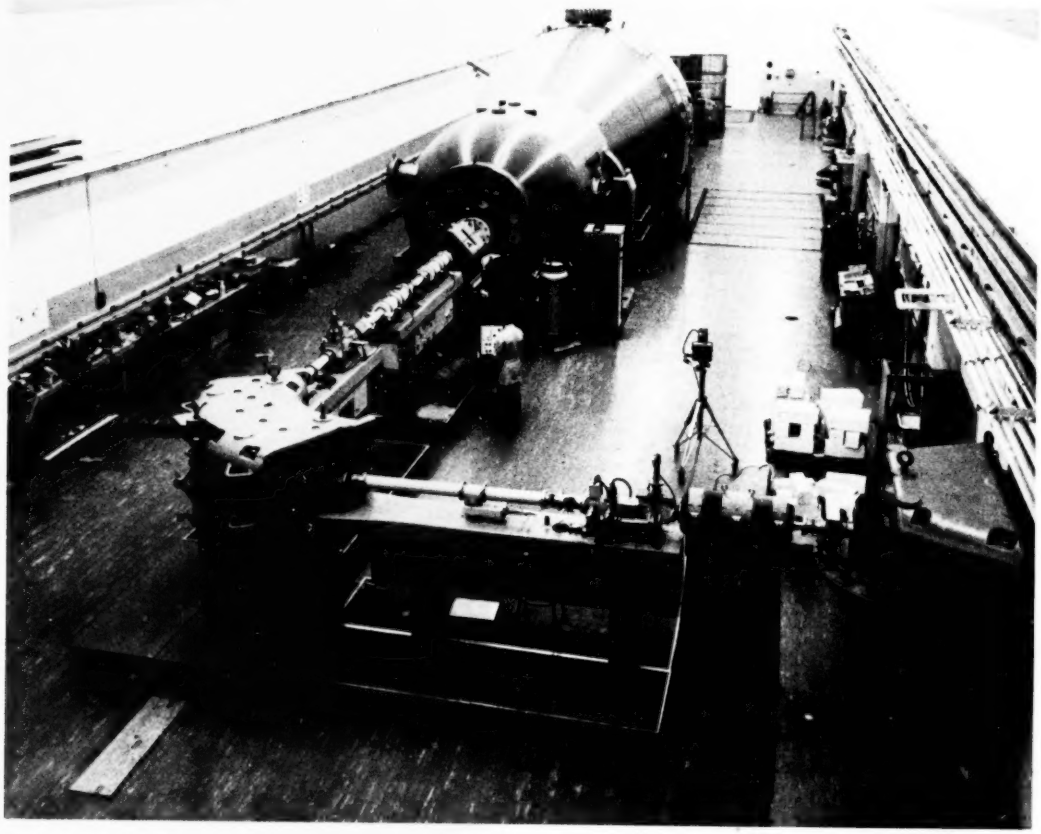
Group Two

Answer ONE of the following three questions.

1. a) Explain the function of the moderator in a nuclear reactor.
   b) Why is heavy water an effective moderator?

2. a) Describe briefly the liquid-drop model of the nucleus.
   b) List one nuclear phenomenon that is "explained" by this model.

3. The picture shows the "Emperor" tandem Van de Graaff particle accelerator at Yale University and some of its associated apparatus.



What is the piece of equipment marked by the arrow? What do you think its functions are?

Directions

This test consists of fifteen multiple-choice questions and eight problem-and-essay questions, divided into two groups. Answer ALL multiple-choice questions by marking the letter corresponding to the one best answer. Answer THREE of the problem-and-essay questions from Group One and ONE from Group Two. Spend about 15 minutes on the multiple-choice questions, 5 minutes on each of the problem-and-essay questions from Group One and 10 minutes on the problem-and-essay question from Group Two.

1. Biologists are learning more about the metabolism of plants and animals through the use of

A. high-energy particle accelerators.
B. cloud-chamber photography.
C. isotopic tracers.
D. mass spectroscopy.
E. cosmic rays.

2. Alpha particles

A. are electromagnetic radiation of high frequency.
B. are negatively charged particles.
C. have the highest penetr ing power of the three types of radiation emitted by radioactive elements.
D. produce the greatest amount of ionization per centimeter of the three kinds of emissions from radioactive nuclei.
E. have the same properties as electrons.

3. Which of the following is (are) true of beta particles?

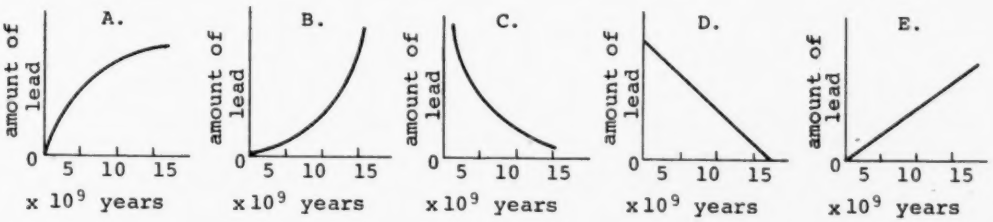
1. They originate from atomic nuclei.
2. They have the same properties as electrons.
3. If they travel through air, they produce ionization.

A. 1 only
B. 1 and 2 only
C. 1 and 3 only
D. 2 and 3 only
E. 1, 2 and 3

4. The electron volt (abbreviated eV) is a unit of

A. energy.
B. speed.
C. voltage.
D. radioactivity.
E. force.

5. Which graph best represents the change with time of the amount of stable lead present in a sample that was originally pure uranium 238?



6. ALL EXCEPT ONE of the following particles can be accelerated by an electric or magnetic field. Which one is the exception?

A. electron
B. proton
C. neutron
D. alpha particle
E. deuteron ($_1H^2$ nucleus)

Questions 7 and 8 list key advances in the field of nuclear physics. From the key below, select the person whose contribution is described.

A. Becquerel
B. Curie
C. Soddy
D. Chadwick
E. Fermi

7. discovered radium

8. discovered the neutron

9. Isotopes of an element have

A. different masses and different atomic numbers.
B. the same chemical properties but different masses.
C. the same chemical properties but different atomic numbers.
D. the same mass but different atomic numbers.
E. the same atomic number but different chemical properties.

10. The law of decay of radioactive samples is a statistical law. This implies that

1. it is only applicable to samples containing a large number of atoms.
2. it can predict little about the time of decay of an individual atom.
3. it makes no assumptions as to why atoms disintegrate.

A. 1 only
B. 2 only
C. 1 and 2 only
D. 1 and 3 only
E. 1, 2 and 3

Questions 11 and 12 are statements that identify one of the equation(s) in the key below. Select the equation identified by each statement.

A. $_0n^1 + {}_{94}Pu^{239} \longrightarrow {}_{56}Ba^{141} + {}_{38}Sr^{96} + 3{}_0n^1$

B. $4{}_1H^1 \longrightarrow {}_2He^4 + 2{}_{+1}e^0 + 2\nu + \gamma$

C. $_0n^1 + {}_{92}U^{238} \longrightarrow {}_{92}U^{239}$; $\quad {}_{92}U^{239} \longrightarrow {}_{93}Np^{239} + {}_{-1}e^0 + \bar{\nu}$

D. $_0n^1 + {}_{13}Al^{27} \longrightarrow {}_{13}Al^{28}$

E. $_1H^2 + {}_{80}Hg^{199} \longrightarrow {}_{79}Au^{197} + {}_2He^4$

11. the formation of a transuranium element

12. release of energy in stars

13. In 1939, Hahn and Strassman identified barium as one of the disintegration products produced when uranium was bombarded with neutrons. The importance of this discovery was that it suggested that

A. the nucleus of the uranium atom could be split apart.
B. the uranium atom is really several barium atoms bound together.
C. uranium could be made radioactive.
D. uranium and barium were isotopes of the same element.
E. neutrons were converted into barium atoms.

14. Rutherford identified three types of radiation emitted from radium: alpha, beta, and gamma. If these radiations are listed in order of increasing penetrating power, with the least penetrating listed first, the order is

A. alpha, beta, gamma.
B. beta, gamma, alpha.
C. gamma, alpha, beta.
D. beta, alpha, gamma.
E. alpha, gamma, beta.

15. The purpose of a moderator in an atomic reactor is to

A. provide neutrons for the fission process.
B. react with the uranium to release energy.
C. slow down fast neutrons to increase the probability of fission.
D. release energy by combustion to keep the reactor "critical."
E. absorb the dangerous gamma radiation.

TEST B

PROBLEM-AND-ESSAY QUESTIONS

Group One

Answer THREE of the following four questions.

1. "Since the half-life of radium is 1620 years, this element will have vanished from the earth by the year 6000." Do you agree with this statement? Discuss your answer.

2. By bombarding mercury 198 with neutrons a modern physicist can produce gold. Does this satisfy the ancient alchemists' dream of producing gold from other metals? Discuss your answer.

3. The average binding energy per particle in the nuclide Ba^{141} is greater than the average binding energy per particle in the nuclide Ra^{222}. State one implication of these data.

4. Explain the statement,"Pb^{214} and Pb^{206} are isotopes of lead."

5. What do you think the man in the picture is doing with the instrument that he is holding?

PROBLEM-AND-ESSAY QUESTIONS

Group Two

Answer ONE of the following three questions.

1. Discuss the differences and similarities between fusion and fission.

2. Describe briefly the theory of radioactive transformation as proposed by Rutherford and Soddy.

3. In 1963 most nations agreed to end nuclear bomb tests in the atmosphere. This agreement was reached because of concern over the undesirable effects of radioactive fallout from such tests. Comment briefly on the reasons for this concern over the effects of radioactive fallout.

Test C

Directions

Answer ALL forty multiple-choice questions by marking the letter corresponding to the one best answer.

Questions 1, 2 and 3 refer to the following statement: A certain isotope of carbon is represented by the symbol ${}_6C^{13}$.

1. How many electrons are there in a neutral atom of this isotope?

A. 0
B. 6
C. 7
D. 13
E. 19

2. How many protons are there in a neutral atom of this isotope?

A. 0
B. 6
C. 7
D. 13
E. 19

3. How many neutrons are there in a neutral atom of this isotope?

A. 0
B. 6
C. 7
D. 13
E. 19

4. The charge on a proton is expressed in

A. amperes.
B. coulombs.
C. electron volts.
D. ohms.
E. joules.

5. Radioactive bismuth has a half-life of 5 days. A one-gram sample of bismuth is prepared. After 5 days, the amount of bismuth in the sample is very close to

A. 1/16 g.
B. 1/8 g.
C. 1/4 g.
D. 1/2 g.
E. 1 g.

TEST C

6. ALL EXCEPT ONE of the following statements are true. Which is the exception?

A. Radioactivity is a natural characteristic of some elements.
B. Radioactive isotopes can be produced in the laboratory.
C. Radioactive isotopes decay by the emission of particles from the nucleus.
D. All isotopes are radioactive.
E. There is a wide variety of decay rates for radioactive elements.

7. Three of the names listed below refer to the same thing. Which one does NOT?

A. electrons
B. beta particles
C. cathode rays
D. alpha particles

8. The radiation from a sample of Kr^{85} decreases to one-third of the original intensity I_o in a period of 18 years. What would be the intensity after 18 more years?

A. I_o
B. $1/2\ I_o$
C. $1/3\ I_o$
D. $1/6\ I_o$
E. $1/9\ I_o$

9. Suppose that a new type of radiation, the T particle, is discovered among the radiations emitted by certain elements. Suppose measurements yield the following information:

1. The charge-to-mass ratio of the T particle is one third that of the charge-to-mass ratio of a proton.
2. T particles are deflected in a magnetic field in the same direction as alpha particles.

Which one of the following symbols could describe the particle?

A. $-{}_{1/3}T^{1}$
B. $-{}_{1}T^{3}$
C. ${}_{1}T^{3}$
D. $-{}_{3}T^{1}$
E. ${}_{3}T^{1}$

10. Rutherford identified three types of radiation emitted from radium: alpha, beta, and gamma. If these radiations are listed in order of increasing penetrating power, with the least penetrating radiation listed first, the order is

A. alpha, beta, gamma.
B. beta, gamma, alpha.
C. gamma, alpha, beta.
D. beta, alpha, gamma.
E. alpha, gamma, beta.

Question 11 refers to the following information:

An isotope of polonium is gradually transmuted to lead according to the following decay scheme (the half-life for each member is listed below its symbol).

Po^{218}	$\longrightarrow$	Pb^{214}	$\longrightarrow$	Bi^{214}	$\longrightarrow$	Po^{214}	$\longrightarrow$	Pb^{210}	$\longrightarrow$	Bi^{210}	$\longrightarrow$	Po^{210}	$\longrightarrow$	Pb^{206}
3.05 min.		26.8 min.		19.7 min.		1.64×10^{-4} sec		21.4 years		5.0 days		138.4 days		stable

11. If we have a pure sample of Po^{218} initially, which member of the series will be present in the greatest amount after one day?

A. Pb^{206}

B. Po^{210}

C. Pb^{210}

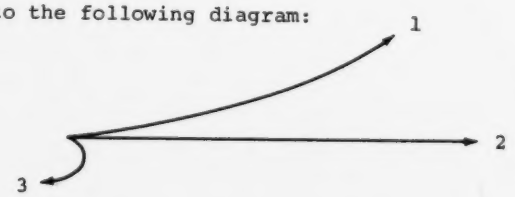
D. Bi^{214}

E. Pb^{214}

12. ALL EXCEPT ONE of the following particles leaves a track of condensed vapor when it passes through a cloud chamber. Which one is the exception?

A. electron
B. neutron
C. positron
D. alpha particle
E. proton

Question 13 refers to the following diagram:



13. Assume you know nothing about the rays from a radioactive isotope except that, in a uniform magnetic field, they behave as shown in the diagram above. (The magnetic field is directed into the paper.) Which one of the following statements must be true about the rays which move along paths 1, 2 and 3?

A. 3 has a charge of larger magnitude than 2.
B. 1 consists of electromagnetic radiation.
C. The speed of 3 is different from that of 2.
D. 3 consists of particles of smaller mass than 2.
E. 1 and 3 both consist of charged particles.

14. Which one of the following is true of the most stable nuclides? They have

A. even numbers of protons and neutrons.
B. odd numbers of protons and neutrons.
C. even numbers of protons, odd numbers of neutrons.
D. odd numbers of protons, even numbers of neutrons.
E. equal numbers of protons and neutrons, regardless of whether odd or even.

15. Nuclide A decays by emitting a beta particle and forms nuclide B. Compared to nuclide A, nuclide B has

A. a charge of one unit more, and practically the same mass.
B. a charge of one unit more, and a mass one unit less.
C. a charge of one unit less, and a mass one unit more.
D. a charge of one unit less, and a mass one unit less.
E. a charge of one unit less, and a mass two units less.

16. Which of the following pairs of nuclei are isotopes of the same element?

A. two nuclei with the same numbers of neutrons, but different numbers of protons
B. a nucleus of carbon and a nucleus of nitrogen, both nuclei with the same mass
C. two nuclei that carry different electric charges, but have the same mass
D. two nuclei in which the number of protons equals the number of neutrons
E. two nuclei that have the same numbers of protons, but with different masses

17. ALL EXCEPT ONE of the following particles can be accelerated by an electric or magnetic field. Which one is the exception?

A. electron
B. proton
C. neutron
D. alpha particle
E. deuteron ($_1H^2$ nucleus)

18. An atom of mass number 11 and atomic number 5 captures an alpha particle and then emits a proton.

The mass number of the resulting atom will be

A. 10.
B. 11.
C. 12.
D. 13.
E. 14.

19. The discovery of isotopes was difficult because

A. isotopes of one element have the same chemical properties.
B. only obscure elements have isotopes.
C. isotopes decay rapidly.
D. isotopes are found only in the three radioactive series.

Questions 20 and 21 require the completion of nuclear equations. From the following key select the particle that must be inserted in the space between the parentheses to balance the equation.

A. $_{-1}e^{0}$
B. $_{+1}e^{0}$
C. $_{1}H^{1}$
D. $_{0}n^{1}$
E. $_{2}He^{4}$

20. $_{13}Al^{27} + {}_{1}H^{2} \longrightarrow (\quad) + {}_{12}Mg^{25}$

21. $_{5}Be^{11} + {}_{2}He^{4} \longrightarrow (\quad) + {}_{7}N^{14}$

22. The chemical properties of an atom are determined by its

A. mass number.
B. number of isotopes.
C. atomic number.
D. nuclear binding energy.

23. Electrons moving at right angles to a uniform magnetic field travel in a circular path. The radius of the circle is 1.2 meters. If the electrons had twice the speed while moving through the same magnetic field, the radius of their circular path would be

A. 0.3 m.
B. 0.6 m.
C. 1.2 m.
D. 2.4 m.
E. 4.8 m.

$$\begin{bmatrix} F_{magnetic} = qvB \\ F_{centripetal} = \frac{mv^2}{R} \end{bmatrix}$$

24. ALL EXCEPT ONE of the following developments of modern physics date from the period 1890-1915. Which one is the exception?

A. discovery of radioactivity
B. nuclear model of the atom
C. discovery of isotopes
D. discovery of nuclear fusion
E. relativity theory

TEST C

Questions 25 and 26 refer to important advances in the field of nuclear physics. From the key below, select the physicist whose contribution is described.

A. Becquerel
B. Fermi
C. Chadwick
D. Compton
E. Rutherford

25. first self-sustaining nuclear reaction

26. first artificial transmutation

27. An example of binding energy is the

A. mass lost by protons and neutrons when they combine to form an atomic nucleus.
B. energy of alpha particles emitted by a radioactive nuclide.
C. relativistic mass gained by accelerated particles.
D. minimum energy of neutrons that collide with uranium or plutonium to produce fission.
E. mass added to a proton to produce a neutron.

Questions 28, 29 and 30 are statements that identify one of the equations in the key below. Select the equation identified by each statement.

A. ${}_0n^1 + {}_{94}Pu^{239} \longrightarrow {}_{56}Ba^{141} + {}_{38}Sr^{96} + 3{}_0n^1$

B. ${}_4{}_1H^1 \longrightarrow {}_2He^4 + 2{}_{+1}e^0 + 2\nu + \gamma$

C. ${}_0n^1 + {}_{92}U^{238} \longrightarrow {}_{92}U^{239}$; ${}_{92}U^{239} \longrightarrow {}_{93}Np^{239} + {}_{-1}e^0 + \bar{\nu}$

D. ${}_0n^1 + {}_{13}Al^{27} \longrightarrow {}_{13}Al^{28}$

28. the formation of a transuranium element

29. production of energy in stars

30. nuclear fission

31. If these radiations are listed in order of increasing deflection by a given magnetic field, starting with the radiation least deflected, the order is

A. alpha, beta, gamma.
B. beta, gamma, alpha.
C. gamma, alpha, beta.
D. beta, alpha, gamma.
E. alpha, gamma, beta.

32. Biologists are learning more about the metabolism of plants and animals through the use of

A. high-energy particle accelerators.
B. cloud-chamber photography.
C. isotopic tracers.
D. mass spectroscopy.
E. cosmic rays.

33. The "decay constant" is defined as the fraction of remaining atoms that decays in a unit time interval. The decay constant of a bismuth isotope, with a half-life of 5 days, is 0.14 per day. After 10 days the decay constant will have a value of

A. 2 times larger than the present value.
B. the same as the present value.
C. 1/4 the present value.
D. 1/8 the present value.

34. All isotopes of hydrogen

A. have the same mass.
B. are man-made.
C. are radioactive.
D. have identical physical properties.
E. have the same electric charge on the nucleus.

35. The following are related events:

1. Becquerel's discovery of radioactivity
2. the discovery of x-rays
3. Rutherford's discovery of the nucleus

Order these three events in time, with the earliest event listed first.

A. 1, 2, 3
B. 1, 3, 2
C. 2, 1, 3
D. 2, 3, 1
E. 3, 1, 2

36. A plasma is

A. the shield of concrete surrounding nuclear reactors.
B. the carbon rods inserted inside nuclear reactors.
C. an ionized gas containing both positive and negative ions.
D. the fluid required to cool nuclear reactors.
E. a region in a reactor occupied only by neutrons.

Questions 37-39 describe some technical features of nuclear reactors that are also identified by the technical terms in the key. Match the technical words in the key with the descriptive statement.

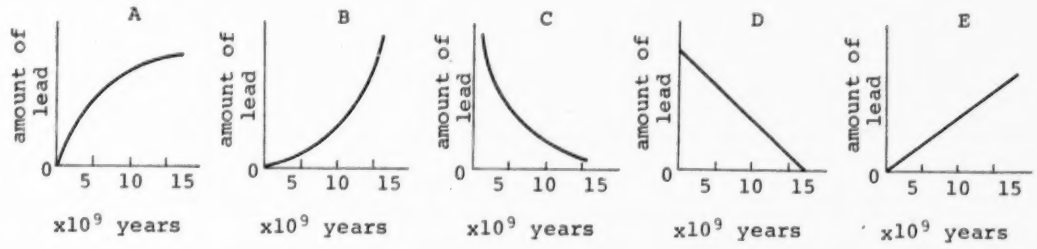
A. half-life
B. critical size
C. control rods
D. moderator
E. plasma

37. There is an approximate balance between production of neutrons and loss of neutrons due to capture or escape.

38. Neutrons are slowed down by substances such as water, heavy water, or carbon.

39. Substances such as cadmium or boron, that readily absorb neutrons, are present.

40. Which graph best represents the change with time of the amount of stable lead present in a sample that was originally pure uranium 238?



Directions

This test consists of eight questions in two groups. Answer only FOUR of the five questions in Group One, and only TWO of the three questions in Group Two. Spend about 5 minutes on each of the questions from Group One, and 10 minutes on each of the questions from Group Two.

Group One

Answer FOUR of the following five questions.

1. A nucleus of $_8O^{16}$ will absorb a neutron to form a new stable nuclide.
   a) Write the equation for this nuclear reaction.
   b) How is the new nuclide related to $_8O^{16}$?

2. Calculate the binding energy of $_2He^4$ in MeV,

   given: mass of $_2He^4$ atom = 4.002403 amu
   mass of e^- = 0.000549 amu
   mass of p = 1.007276 amu
   mass of n = 1.008665 amu
   1 amu = 931 MeV

3. How did the observation of radioactivity conflict with the traditional atomic-molecular theory of matter?

4. What evidence indicated that radioactive emissions, as first observed by Becquerel, were not the same as x rays?

5. Describe briefly two biological or medical applications of nuclear physics.

Group Two

Answer TWO of the following three questions.

1. Why is the decay rate of a radioactive sample expressed in terms of "half-life" rather than "total lifetime?"

2. In terms of the Rutherford-Bohr model of the atom, discuss
   a) how an atom changes when it emits an alpha particle;
   b) how an atom changes when it emits a beta particle.

3. a) Describe briefly the shell model of the nucleus.
   b) List one nuclear phenomenon that is "explained" by this model.